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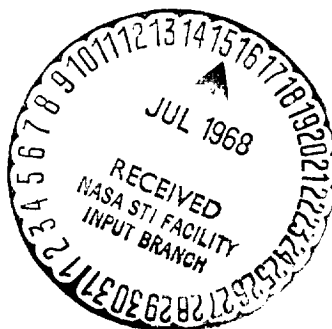
1100 Seventeenth Street, N.W. Washington, D. C. 20036

**SUBJECT:** Saturn V and Spacecraft Breakup  
Problems - Case 320**DATE:** March 29, 1968**FROM:** J. J. O'ConnorABSTRACT

The Saturn V engine shutdown sequence during any high-q abort can cause launch vehicle breakup (and probably explosion) by removing the axial compression loads which tend to offset the tension component of the bending moment loads. Such a breakup within 0.5 second violated the MSC warning time requirement of two seconds. MSFC has been unable to find a way of eliminating or delaying the breakup. Recently revised MSC requirements which call for specific separation distances were interpreted by MSFC to allow safe abort at high-q even with launch vehicle breakup. It is not clear how such a severe problem could so completely disappear.

The transient or dynamic loads generated by loss of thrust of an S-IC control engine exceed the structural capability of the CM/SM joint during almost all of the S-IC flight phase. This problem has been confirmed (and even enlarged) by MSFC simulation studies using the most recent MSC structural data. Tentative solutions suggested by MSFC call for significant beef-up, automatic abort or escape tower jettison.

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BREAKUP PROBLEMS (Bellcomm, Inc.) 5 p

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Problems - Case 320

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MEMORANDUM FOR FILE

On March 15, 1968, special presentations were given at MSFC for Dr. Rudolph by C. C. Hagood/R-AERO-FF and J. T. Stevens/R-P&VE-SL on two structural breakup problems. One of the problems, Saturn V breakup during high-q aborts, appears to have been resolved by reduced MSC requirements. The other problem, spacecraft breakup due to S-IC engine-out failures, has been confirmed by recent MSC input data and steps are being taken to make MSC management aware of the magnitude of this problem.

SATURN V BREAKUP

Saturn V breakup during high-q aborts would be caused by the shutdown of the S-IC engines. Engine thrust normally supplies compressive loads which tend to relieve the tensile component of the bending moment loads. The sudden elimination of the compressive loads due to engine shutdown during an abort sequence would cause the several launch vehicle joints to fail in tension, probably resulting in a launch vehicle explosion. The MSC requirement for a successful abort had been a two second warning time, but the launch vehicle breakup (and explosion) occurs in about one-half second.

This problem was identified about a year ago, and in the attempt to eliminate or delay the breakup, MSFC has examined many possibilities including commanded staging (controlled breakup) and delayed S-IC Center Engine Cutoff. No promising solution was uncovered, so the approach taken was to minimize the probability of a high-q abort. One specific example of this approach is the pending change to incorporate a backup guidance system.

The above information is background; what was actually presented to Dr. Rudolph was a graph of separation distance versus (flight) time of abort. This graph, hereinafter called the separation criterion, showed the minimum initial distance between the Command Module (CM) and the center of the explosion to avoid a peak pressure of 6.1 psi when, and if, the shock front envelopes the CM. (This 6.1 psi value is associated with damage to the parachutes, flotation gear, etc.) The graph was based on an S-IVB explosion with 15 percent TNT yield.

This separation criterion was presented as a new, albeit preliminary, MSC requirement; presumably it supercedes the previous requirement quoted as warning time. MSFC analysis indicates that this separation criterion can be met in (almost) all abort cases. The remainder of the meeting appears to have been based on the assumption that elimination or delay of launch vehicle breakup during high-q aborts is not required. However, MSFC would like to see the breakup occur at the cleanest separation plane which is the aft joint of the S-II Interstage. To obtain this, MSFC plans to beef-up the structurally weaker joint at the forward end of the S-II Interstage. The change will involve the use of larger tension straps at this joint.

Post-meeting reflection leads me to the following tentative conclusions:

- a. The separation criterion may be conservative due to the use of 15 percent TNT yield for  $O_2/H_2$  propellants; the yield of the S-IVB-503 stage explosion in January, 1967, was closer to one percent. The separation criterion may be unconservative in that it only includes S-IVB propellant quantities; that is, it does not (yet) include S-II and S-IC propellant quantities.
- b. If this separation criterion indicates a safe abort is possible at high-q in the presence of launch vehicle breakup, a great deal of the justification for a backup guidance system is thereby eliminated.
- c. The complete elimination of such a severe problem by a re-definition of the requirements seems too good to be true. Indeed re-examination of previously available explosion-separation data\* fails to uncover any basic change in the requirements. I would not be surprised to see this problem re-surface when the additional MSC requirements data are available.

#### SPACECRAFT BREAKUP

Over a year ago MSFC realized that the loss of thrust on a single S-IC control engine applies a horrendous bending moment throughout the vehicle. This is due to the fact that the engines are not canted to go through the vehicle center of gravity since this would significantly reduce payload capability. The weak points of the launch vehicle have been identified and malfunction survival assured by structural tests and/or structural beef-up of these joints.

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\*"Minutes of Engine-out and EDS Analyses Meeting," R-AERO-P-440-67, August 10, 1967.

Loads data for engine-out cases were transmitted to MSC but the validity of the calculation was questioned. There has been a series of intercenter exchanges and, hopefully, increasing confidence in the results. Updated analyses show CM/SM joint loads for SA-504 some 12% above the previous estimate and some 30% above the SA-503 loads estimate. The SA-504 analysis includes increased payload mass and decreased S-II stiffness.

The bending moment for engine-out failures exceeds the CM/SM joint capability for almost the entire S-IC flight. The peak value of  $7 \times 10^6$  in-lbs so exceeds the capability that MSC will probably not continue a planned structural test of the joint. The load is largely dynamic and specifically related to the mass and center of gravity of the Launch Escape System. The CM/SM joint is weakest in tension; first the tension strap itself fails and then its junction to the inner pressure vessel. The joint is also weak in compression, which would result in crippling of the CM inner structure sidewall.

The loads are very difficult to analyze because of the six CM/SM pads; MSFC refers to them as two redundant sets-of-three load paths. The problem is further complicated by the unequal angular spacing ( $50^\circ$ ,  $60^\circ$ , and  $70^\circ$ ) of these pads. To better analyze the problem MSC has requested MSFC to furnish loads data at the SM/SLA and SLA/IU interfaces.

While MSFC realizes that this is essentially an MSC problem, possible solutions were suggested: (a) beef-up, (b) automatic abort, and (c) tower jettison. Adequate beef-up of the joint might involve requalification of the CM/SM separation system. An automatic abort on one S-IC engine-out might avoid the rapid buildup of loads (0.8 second) but would require a change of abort philosophy and hardware. It would also reduce alternate mission capability. The rather startling possibility of jettisoning the tower shows that the catastrophic loads are caused by the tower. Its jettisoning could only be justified by a trade-off which examines the risk of continuing the flight without the tower.

In order to bring these results to the attention of MSC management, Dr. Rudolph will probably write a letter to Mr. Low. There was also a suggestion to brief Dr. Rees on the problem. It was later learned that Boeing-Huntsville has forwarded the results to the Boeing structural task force at MSC and Downey. Boeing-TIE made a brief presentation of this problem to George Hage/MA-A, on March 18, 1968. The forthcoming Crew Safety Review might also be able to give the problem proper exposure.

SUMMARY

Launch vehicle breakup during high-q aborts seemed to be an insurmountable problem. The acceptability of breakup in light of new abort separation criterion seems too good to be true. If breakup does not preclude safe abort, this fact should be publicized to terminate activity on various partial solutions such as backup guidance. Spacecraft breakup due to an S-IC engine failure seems to be confirmed by intercenter exchange of data. Existence of this problem should be publicized so that a timely solution can be derived.

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